Sophisticated revenue-based cartel penalties vs overcharge-based penalties

Katsoulacos, Y.; Motchenkova, Evgenia; Ulph, D.

2018

Sophisticated revenue-based cartel penalties vs overcharge-based penalties

Research Memorandum 2018-1

Yannis Katsoulacos
Evgenia Motchenkova
David Ulph

Sophisticated revenue-based cartel penalties vs overcharge-based penalties [1]

Yannis Katsoulacos[2]
Evgenia Motchenkova[3]
David Ulph[4]

Abstract

In this paper we analyse a new sophisticated revenue-based penalty regime proposed in Katsoulacos et al. (2017), in which the penalty *base* is the revenue of the cartel but the penalty *rate* increases in a systematic way with the cartel overcharge. This regime formalises how revenue can be used as the base while taking into account the severity of the offence. In a homogeneous product linear demand oligopoly model we show that this hybrid regime can replicate the desirable welfare properties of overcharge-based penalties identified in Katsoulacos et al. (2015). We also demonstrate that for a wide range of parameter values a sophisticated revenue-based regime can be superior in its welfare impact to the overcharge-based regime.

JEL Classification: L4 Antitrust Policy, K21 Antitrust Law, D43 Oligopoly and Other Forms of Market Imperfection.

Keywords: Antitrust Penalties, Antitrust Enforcement, Antitrust Law, Cartels.

---

[1]We are grateful to Joe Harrington, Frederic Jenny, Tom Ross, the referees and the editor, as well as the participants of the 12th Annual CRESSE Conference (July 2017) for helpful comments and to the Tinbergen Institute, VrijeUniversiteit Amsterdam, Short-term Visitor Program for financial support.
[2]Department of Economic Science, Athens University of Economics and Business, Patission 76, Athens 104 34, Greece. Email: ysk@hol.gr
[3]Department of Economics, VrijeUniversiteit Amsterdam, TILEC and Tinbergen Institute, De Boelelaan 1105, 1081 HV Amsterdam, The Netherlands. Email: emotchenkova@feweb.vu.nl
[4]School of Economics and Finance, University of St Andrews St Andrews, KY16 9AR, Scotland. Email: du1@st-andrews.ac.uk

1. Introduction

Recent literature on antitrust sanctioning focuses on the analysis of second-best monetary penalties. This analysis presumes that there are a variety of factors such as bankruptcy considerations and proportionality, which mean that penalties cannot be set so as to deter all or even most cartels.[5] So, a proper second-best welfare comparison has to take into account the effects of a given penalty regime on both deterrence and on the price set by those cartels that do form.[6]

The extensive overview of the second-best penalty regimes is contained in e.g. Bageri et al. (2013) or Katsoulacos et al. (2015, 2017). Bageri et al. (2013) conclude that currently employed revenue-based penalty regime is distortive as it induces cartel prices higher than those in the absence of antitrust enforcement. Katsoulacos et al. (2015) propose new overcharge–based penalties and show that those would allow mitigating the distortive price effects of revenue-based regime. Moreover they show that, taking into account both price and deterrence effects, overcharge–based penalties welfare-dominate the currently employed revenue-based penalties. However, as discussed in Katsoulacos et al. (2017), overcharge–based penalties are subject to criticisms on the grounds of high implementation costs as their assessment requires information about counterfactual price and volume of sales. While revenue-based penalties are easy to implement as information about turnover/revenue is publicly observable.

With the aim to reduce implementation problems, while retaining the desirable welfare properties of overcharge-based penalties, Katsoulacos et al. (2017) propose and analyse a *sophisticated revenue-based penalty regime* in which the penalty *base* is the revenue of the cartel but the penalty *rate* depends on the cartel overcharge. Thus, this proposed regime formalises how revenue can be used as the base while taking into account the severity of the offence. They show that this hybrid regime can replicate the desirable welfare properties of overcharge-based penalties, while having relatively low levels of implementation costs, concluding that the proposed penalty regime deserves very serious attention from competition authorities.

---

[5]Difficulties of first-best solutions in practice were discussed in e.g. Bos and Schinkel (2006), Buccirossi and Spagnolo (2007), Harrington (2010), Bageri et al. (2013), Katsoulacos and Ulph (2013) and Houba et al. (2017).
[6]See e.g. Harrington (2004, 2005), Houba et al. (2010), Katsoulacos and Ulph (2013), Katsoulacos at al. (2015) and Bos et al. (2017) for theoretical analysis of the effects of various penalty regimes on cartel pricing and /or deterrence. The empirical analysis is provided in e.g. Levenstein and Suslow (2011, 2012, 2014), Schinkel (2007), Veljanovski (2007), Connor and Lande (2008), Allain et al. (2011), Boyer and Kotchoni (2015) or Spagnolo and Marvão (2016).

Katsoulacos et al. (2017) provide a detailed comparison of price and deterrence effects of the sophisticated revenue-based penalties to the currently employed standard revenue-based penalties. However, they do not compare price and deterrence effects of the sophisticated revenue-based penalties to the overcharge-based regime. The aim of this note is to provide such a comparison and to demonstrate that there exists a range of parameter values where the sophisticated revenue-based penalty regime is welfare superior relative to the overcharge-based regime.

The structure of the paper is as follows. Section 2 provides a description of the model. Section 3 provides a detailed comparison of the price effects and deterrence properties of the two penalty regimes and demonstrates that for a range of policy relevant parameter values a sophisticated revenue-based regime can be superior in its welfare impact to the overcharge-based regime. Section 4 concludes.

2. The Model

The model is the repeated game model of cartel formation and pricing behaviour employed in Katsoulacos et al. (2015, 2017). We consider an economy comprising a range of types of industry, in each of which there is a homogeneous product produced by a number of firms. Firms have the same constant unit costs of production. For a typical industry $c > 0$ denotes the common unit costs of production and demand is given by the downward-sloping linear demand function $Q(p) = a - p$, $a > c$. So an *industry type* is characterised by $c, a, Q(\cdot)$.

We assume Bertrand competition. So the "but-for" price, output, revenue and profit - denoted respectively by p^B, Q^B, R^B and π^B - are given by: $p^B = c, Q^B = Q(c) = a - c$, $R^B = cQ(c) = c(a-c)$ and $\pi^B = 0$. Also, for a cartel to be able to effectively raise price above the "but-for" level all firms in an industry have to join the cartel. p^M denotes the monopoly price.

If a cartel forms and sets a price $p > c$ then the percentage overcharge is $\theta = (p-c)/c$. So the price is given by $p = c(1+\theta)$. For any given price / overcharge set by a cartel the associated industry operating profits and revenue will be:

$$\begin{aligned} \pi(\theta) &= c\theta Q\big(c(1+\theta)\big) = c\theta(a - c(1+\theta)) \\ R(\theta) &= c(1+\theta)Q\big(c(1+\theta)\big) = c(1+\theta)(a - c(1+\theta)) \end{aligned} \tag{1}$$

If industry operating profits and revenue are expressed as functions of cartel price, we have:

$$\pi(p)=(p-c)(a-p) \\ R(p)=p(a-p) \tag{2}$$

There is a Competition Authority (CA) that investigates, discovers, prosecutes and penalises cartels. We focus on the following two penalty regimes:

(a) *Sophisticated Revenue-Based Penalty Regime*, SR. Here the penalty base is cartel revenue, but now the penalty rate applied to that base is a non-decreasing linear function of the cartel overcharge $\tilde{\rho}_{SR}\theta>0$. So the financial penalty imposed under this regime will be:

$$F_{SR}(\theta)=\tilde{\rho}_{SR}\theta c(1+\theta)Q\big(c(1+\theta)\big) \quad or \quad F_{SR}(p)=\frac{\tilde{\rho}_{SR}(p-c)p(a-p)}{c}. \tag{3}$$

(b) *Overcharge-Based Penalty Regime,* O. Here, as defined in Katsoulacos et al. (2015), the penalty base is the absolute overcharge multiplied by counterfactual output, and there is a penalty rate $\rho_O>0$ applied to that base. So the financial penalty imposed under this regime will be:

$$F_O(\theta)=\rho_O\theta cQ\big(c\big) \quad or \quad F_O(p)=\rho_O(p-c)(a-c). \tag{4}$$

Notice that under these regimes the penalty paid will vary with the cartel overcharge, which can either be because of the design of the regime or because of the way in which the penalty base varies with the overcharge.

Let β, $0\le\beta<1$ denote the probability that in each period a cartel is detected, successfully prosecuted and penalised according to one of penalty schedules specified above. We follow the existing literature on both the type and level of penalties and assume that β is independent of θ, and, moreover, its value is common knowledge. In addition, as in Katsoulacos et. al (2015, 2017), we assume that $\beta\rho_O<1$ and $\beta\tilde{\rho}_{SR}<1$.

As in for example, Motta and Polo (2003) and Chen and Rey (2013) - we assume that cartels re-establish following a successful prosecution.[7] Given this and our other assumptions,

[7] In related work we have assumed that collusive activity can re-emerge following successful prosecution. This produces more complex formulae for *V*(.) but does not affect the main qualitative results of the paper, so we stick with the simpler assumption. More specifically, one can assume that, after detection, there is a constant probability γ, $0\le\gamma\le1$ that the cartel will continue in existence after detection. In this case one simply replaces the term $\Delta=n(1-\delta)$ that appears in our analysis with the more general expression $\Delta_\gamma=n(1-\delta)\left[1+\frac{\beta\delta(1-\gamma)}{1-\delta}\right]$. Note that with this generalization we can perform similar analysis but with more general expression for maximum critical level of difficulty of holding the cartel together. Then the unconstrained cartel overcharges under different penalty regimes will not be affected by this change, while the maximum critical difficulty will go down under all relevant regimes, so that the relative performance of various

it follows that the expected present value of profits <u>for a single firm</u> that is a member of a cartel in a given industry that has set an overcharge θ (or price *p*) and faces the penalty regime $r \in \{SR, O\}$ is given by

$$V_r(\theta) = \frac{\pi(\theta) - \beta F_r(\theta)}{n(1-\delta)} \quad or \quad V_r(p) = \frac{\pi(p) - \beta F_r(p)}{n(1-\delta)} \tag{5}$$

where, $n \geq 2$ is the number of firms in the industry and $\delta, 0 < \delta < 1$ is the discount factor. As in Katsoulacos et al. (2015), $\Delta \equiv n(1-\delta)$ denotes the *intrinsic difficulty* of holding the cartel together. For any given *industry type* $\{c, a, Q(.)\}$ there is continuum of possible industries $\{c, a, Q(.), \Delta\}$, where Δ is uniformly distributed on [0,1].

Following standard grim-trigger strategy profile firms collude on cartel price, *p*, in the first period and continue setting *p* as long as no firm defects. If a firm defects from the cartel it sets a price below the cartel price, and, for a single period takes the entire industry profits Any deviation by any firm leads to competition at price *c*, for ever more. We also assume that defecting firm is immune from future prosecution by the CA.[8] Then since the price set by a cartel could be above the monopoly price, $p^M = \arg\max \pi(p)$ a defecting firm trying to make the maximum profits in the single period will set the monopoly price whenever the cartel price is above the monopoly price, but will set a price just a fraction below the cartel price whenever this is at or below the monopoly price, thereby capturing the entire cartel profits. So defection profits are

$$\pi^d(p) = \begin{cases} \pi(p^M), & p > p^M \\ \pi(p), & p \leq p^M \end{cases} . \tag{6}$$

For a cartel to be stable it has to satisfy the cartel stability condition:

$$V_r(p) \geq \pi^d(p). \tag{7}$$

Then the price set by a cartel facing penalty regime, *r,* is that which maximises $V_r(\theta)$ subject to $\theta \geq 0$ and the stability condition (8). We denote this by p_r^C. There are two cases to consider. If the stability condition does not bite then:

---

penalty regimes will be unaffected. So, for the issues with which we are dealing, nothing of substance is affected by this more general set up.

[8]Note the opposite assumption would not affect the main qualitative results of the paper. Allowing for the possibility of prosecuting price-deviating firms does not affect the collusive value in (6). Hence, the unconstrained cartel overcharges under different penalty regimes will not be affected by this change. So the main results about welfare advantages of the sophisticated revenue based regime compared to simple revenue-based structure will not change. On the other hand, the cartel stability condition in (8) will be relaxed, and the degree of deterrence in section 3.3 will be affected but in the same direction for all the penalty regimes.

$$p_r^C = \hat{p}_r^C = \arg\max\left[\pi(p) - \beta F_r(p)\right] \tag{8}$$

and is independent of Δ (though it depends on the *industry type*). On the other hand if the stability condition bites then p_r^C is the solution to

$$\pi(p) = \beta F_r(p) + \Delta \pi^d(p), \tag{9}$$

and so is a function of Δ (as well as the *industry type*).

Finally, we let $\overline{\Delta}_r$ be the maximum critical value of Δ such that, under penalty regime *r*, either the stability condition or the non-negative overcharge constraint bites.[9] Clearly if there were no Competition Authority - and so $\beta = 0$ - then a cartel would always set the monopoly overcharge and the maximum critical value of Δ would be 1. Whereas, once there is an active competition authority enforcing penalties on non-defecting cartel members we must have $\overline{\Delta}_r < 1$.[10] So we can define the *degree of deterrence* achieved by penalty regime *r*, D_r, as the fraction of industries in which cartels would have formed in the absence of a Competition Authority in which they do not form given the presence of a Competition Authority operating penalty regime *r*. Formally:

$$D_r = 1 - \overline{\Delta}_r \; . \tag{10}$$

Having set out the framework, we now investigate how both the cartel price and the degree of deterrence vary depending on which of the two penalty regimes set out above is employed by the Competition Authority. Our focus will be on showing that the sophisticated revenue-based penalty regime can outperform the overcharge-based regime for a wide range of policy relevant parameter values.

3. Analysis of the Welfare Properties

In this section we undertake a systematic comparison of the welfare properties of a sophisticated revenue-based regime with those of an overcharge-based regime. We show that both an overcharge-based and a linear sophisticated revenue-based penalty can achieve the same constant degree of deterrence across all industries. The price effects of these two regimes are different. We can find ranges of parameter values where sophisticated revenue-

---

[9] The maximum critical level of difficulty, Δ, is the direct analogue of the minimum critical discount rate used in much of the literature.

[10] This is why we have confined attention to values of $\Delta \le 1$. The assumption of a uniform distribution just makes it easier to translate statements about $\overline{\Delta}_r$ into statements about proportion of industries where cartels are deterred.

based regime induces lower cartel prices and, hence under deterrence equivalence, would imply higher consumer surplus and higher total welfare.

3.1 *Cartel Pricing*

There are potentially two types of solution – those where the stability constraint (7) does not bite (i.e. unconstrained pricing solutions) and those in which it does (i.e. constrained pricing).

Similar to Katsoulacos et al. (2015) we have that in every type of industry the unconstrained price set by a cartel under an overcharge-based regime, O, is below the monopoly price, i.e. $\hat{p}_O^C < p^M$. More specifically, unconstrained cartel price under an overcharge-based regime is obtained by maximizing $V_O(p)$ with respect to *p*. Recall $V_O(p)$ is given by

$$V_O(p) = \frac{(p-c)(a-p) - \beta\rho_O(p-c)(a-c)}{\Delta}$$

So we have

$$\hat{p}_O^C = \arg\max_p \left[(p-c)(a-p) - \beta\rho_O(p-c)(a-c)\right] = \frac{a+c-\beta\rho_O(a-c)}{2} < \frac{a+c}{2} = p^M \qquad (11)$$

Next, taking into account that $\hat{p}_O^C < p^M$, expressions in (6) and (7) imply that under an Overcharge-Based Regime the cartel stability condition is given by

$$V_O(p) = \frac{(p-c)(a-p) - \beta\rho_O(p-c)(a-c)}{\Delta} \geq (p-c)(a-p) = \pi^d(p)$$

This implies that

$$p \leq a - \frac{\beta\rho_O(a-c)}{(1-\Delta)}. \qquad (12)$$

This expression is a special case of expression (21) in Katsoulacos et al. (2015) for the case of linear demand. This upper bound on *p* is a decreasing function of Δ taking the value *c* when $\Delta = 1-\beta\rho_O < 1$. So there will be a range of values of Δ for which the stability condition bites and constrains the cartel price. So under this penalty regime the overall cartel price is

$$p_O^C = MIN\left[\hat{p}_O^C, a - \frac{\beta\rho_O(a-c)}{(1-\Delta)}\right], \qquad 0 \leq \Delta \leq 1-\beta\rho_O < 1 \qquad (13)$$

Next, following Katsoulacos et al. (2017) we can show that the unconstrained price set by a cartel under a linear sophisticated revenue-based regime is below the monopoly price, i.e. $\hat{p}_{SR}^C < p^M$. More specifically, unconstrained cartel price under a sophisticated revenue-based regime is obtained by maximizing $V_{SR}(p)$ with respect to *p*. Recall $V_{SR}(p)$ is given by

$$V_{SR}(p) = \frac{(p-c)(a-p) - \beta \dfrac{\tilde{\rho}_{SR}(p-c)p(a-p)}{c}}{\Delta}$$

So we have $\hat{p}^{C}_{SR} = \arg\max_{p} \left[c(p-c)(a-p) - \beta\tilde{\rho}_{SR}(p-c)p(a-p) \right]$. And, hence, we obtain

$$\hat{p}^{C}_{SR} = \frac{a+c}{3} + \frac{c}{3\beta\tilde{\rho}_{SR}} - \frac{1}{3\beta\tilde{\rho}_{SR}}\sqrt{c^2\left(1-\beta\tilde{\rho}_{SR}+\left(\beta\tilde{\rho}_{SR}\right)^2\right)+a\beta\tilde{\rho}_{SR}\left(\left(a-c\right)\beta\tilde{\rho}_{SR}-c\right)} < \frac{a+c}{2} = p^M \quad (14)$$

By substituting (2)-(3) into (7) we obtain the cartel stability condition under a *Sophisticated* Revenue-Based Penalty Regime, and can consider to what extent this constrains the cartel overcharge. Under a *Sophisticated* Revenue-Based Penalty Regime the cartel price is below the monopoly price and so (7) becomes:

$$V_{SR}(p) = \frac{(p-c)(a-p) - \beta\tilde{\rho}_{SR}\dfrac{(p-c)}{c}p(a-p)}{\Delta} \geq (p-c)(a-p) = \pi^d(p).$$

which implies

$$p \leq \frac{(1-\Delta)c}{\beta\tilde{\rho}_{SR}}. \quad (15)$$

This upper bound on p is a linear decreasing function of Δ, which takes the value c when $\Delta = 1-\beta\tilde{\rho}_{SR} < 1$. So there will be a range of values of Δ, for which the upper bound in (15) lies below the unconstrained price $\hat{p}^{C}_{SR}$ and so the cartel stability condition bites and constrains the price that the cartel can set. But then the overall cartel price under a this *Sophisticated* Revenue-Based penalty regime is:

$$p^{C}_{SR} = MIN\left[\hat{p}^{C}_{SR}, \frac{(1-\Delta)c}{\beta\tilde{\rho}_{SR}}\right], \quad 0 \leq \Delta \leq 1-\beta\tilde{\rho}_{SR} < 1. \quad (16)$$

So the cartel stability condition constrains the overcharge that cartels set for both the *Sophisticated* Penalty Regime and the Overcharge-Based Penalty Regime. However, without specifying parameter values it is impossible to determine whether the price – either unconstrained or constrained - is higher under one regime than the other. The comparison depends on the shape and the structure of the demand function and on the parameters of the penalty functions. In Figure 1 below we illustrate the case where cartel overcharge under a *Sophisticated* Revenue-Based Penalty Regime (solid line) is below that under an Overcharge-Based Penalty Regime (dotted line). While Figure 2 illustrates the case, where this does not hold.

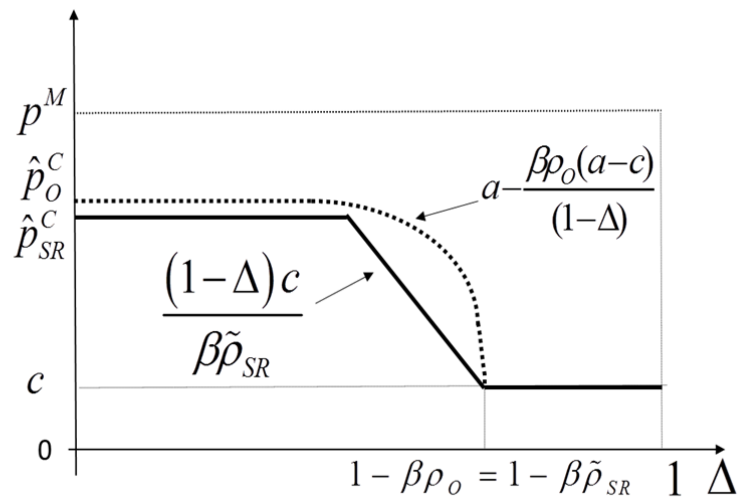

Figure 1: Comparison of Cartel Overcharge Under *Sophisticated* Revenue-Based Penalty Regime (solid line) and Cartel Overcharge Under Overcharge-Based Penalty Regime (dotted line). *Sophisticated* Revenue-Based Penalty Regime welfare dominates Overcharge-Based Penalty Regime

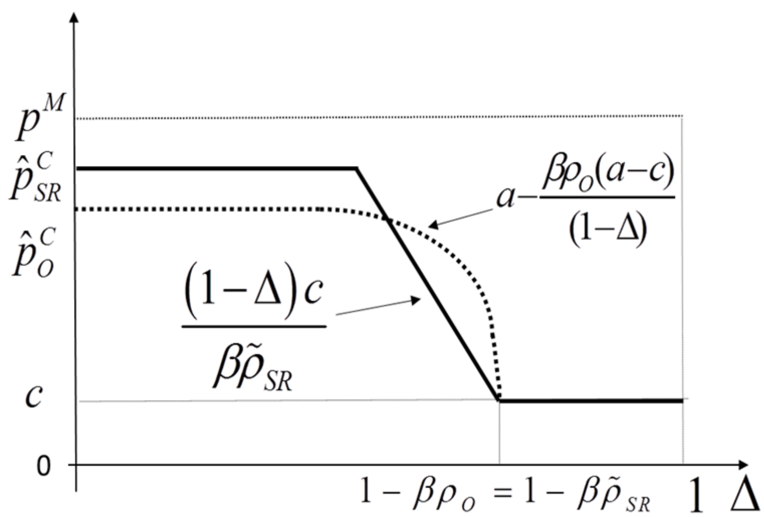

Figure 2: Comparison of Cartel Overcharge Under *Sophisticated* Revenue-Based Penalty Regime (solid line) and Cartel Overcharge Under Overcharge-Based Penalty Regime (dotted line)

3.2 *Deterrence equivalence and welfare comparison*

From the analysis in the previous sub-section we see that the maximum critical level of difficulty of holding a cartel together, $\overline{\Delta}_r$, is determined as the value at which the constrained price is driven to *c* (or equivalently constrained overcharge is driven to zero) for both the *Sophisticated* Revenue-Based Regime and the Overcharge-Based Regime.

From (12) and (15) we immediately have:

$$(i)\overline{\Delta}_{SR} = 1-\beta\tilde{\rho}_{SR} < 1; \quad (ii)\overline{\Delta}_O = 1-\beta\rho_O < 1. \tag{17}$$

Consequently from (10) the degree of deterrence achieved by each of the penalty regimes is:

$$(i)\, D_{SR} = \beta\tilde{\rho}_{SR}; \quad (ii)\, D_O = \beta\rho_O\,. \tag{18}$$

Analysis of (18) implies that that the degree of deterrence achieved by a Sophisticated Revenue-Based Penalty Regime is equal to the toughness of the regime – i.e. the probability of successful prosecution multiplied by $\tilde{\rho}_{SR}$ the constant rate at which the penalty rate is increased with the overcharge. Similarly, the degree of deterrence achieved by an Overcharge-Based Regime is equal to the toughness of this regime – i.e. the probability of successful prosecution multiplied by the penalty rate. Moreover, if $\rho_O = \tilde{\rho}_{SR} = \rho$ then the two regimes will be equally tough and the common degree of deterrence achieved by each of these regimes will be the same (i.e. regimes will be *deterrence equivalent*). So that the fraction of cartels deterred is exactly the same across both regimes.

Since both the *Sophisticated* Revenue-Based regime and the Overcharge-Based Regime achieve the same degree of deterrence across all industries, we can get exact deterrence equivalence industry by industry between these two regimes when penalty rates are equal, i.e. when $\rho_O = \tilde{\rho}_{SR} = \rho$. This will allow direct comparison of the welfare effects of these two regimes. Under deterrence equivalence welfare comparison can be done through comparison of unconstrained and constrained overcharges. The results of this comparison are presented in Proposition 2.

Proposition 1*: If we impose deterrence equivalence, i.e.* $\beta\tilde{\rho}_{SR} = \beta\rho_O = \beta\rho$ *, then*

$$\begin{array}{llll} for & a \geq 5c & we\ have & p_{SR}^C < p_O^C, \quad for\ all \quad 0 < \beta\rho < 1 \\ for & 2c < a < 5c & we\ have & \begin{cases} p_{SR}^C < p_O^C, & when\ \dfrac{5c-a}{3(a-c)} < \beta\rho < 1 \\ p_{SR}^C > p_O^C, & when\ 0 < \beta\rho < \dfrac{5c-a}{3(a-c)} \end{cases} \\ for & c < a \leq 2c & we\ have & p_{SR}^C > p_O^C, \quad for\ all \quad 0 < \beta\rho < 1 \end{array}$$

Proof of Proposition 1: Comparison of expressions in (11) and (14) under deterrence equivalence immediately implies the following results about unconstrained cartel prices:

$$\begin{array}{llll} for & a > \dfrac{5c+3c\beta\rho}{3\beta\rho+1} & we\ have & \hat{p}_{SR}^C < \hat{p}_O^C \\ for & c < a < \dfrac{5c+3c\beta\rho}{3\beta\rho+1} & we\ have & \hat{p}_{SR}^C > \hat{p}_O^C \end{array}.$$

Rewriting the first inequality above we get $\frac{5c-a}{3(a-c)} < \beta\rho < 1$ for $\hat{p}^C_{SR} < \hat{p}^C_O$. Further, we have to analyse two cases: 1) $a \geq 5c$ and 2) $2c < a < 5c$. If $a \geq 5c$, then $\hat{p}^C_{SR} < \hat{p}^C_O$ for all $0 < \beta\rho < 1$. If $2c < a < 5c$, then $\hat{p}^C_{SR} < \hat{p}^C_O$ for sufficiently high $\beta\rho$, i.e. $\frac{5c-a}{3(a-c)} < \beta\rho < 1$, and $\hat{p}^C_{SR} > \hat{p}^C_O$ for low $\beta\rho$, i.e. $0 < \beta\rho < \frac{5c-a}{3(a-c)}$.

Finally, under deterrence equivalence, expressions in (12) and (15) become $p \leq a - \frac{\beta\rho(a-c)}{(1-\Delta)}$ and $p \leq \frac{(1-\Delta)c}{\beta\rho}$. Then if at the point where $\Delta = 1-\beta\rho$ the derivative (slope) of the linear function in (15) is smaller in absolute value than the slope of the function in (12) we should also have that the overall prices $p^C_{SR} < p^C_O,\quad \mathit{for\ all}\quad 0 \leq \Delta \leq 1-\beta\rho$. The above specified condition on the slopes is satisfied when *a>2c,* which trivially holds when $a > \frac{5c+3c\beta\rho}{3\beta\rho+1}$. The analysis of expressions in (12) and (15) adds the third case: 3) $c < a \leq 2c$. In this case we have that overall prices $p^C_{SR} > p^C_O$ for all $0 < \beta\rho < 1$. This completes the proof of Proposition 2. ■

This proposition implies that when demand parameter *a* is sufficiently higher than unit cost *c*, i.e. when $a \geq 5c$, the overall cartel price under the sophisticated revenue-based regime is below that under the overcharge-based regime for any level of the toughness $0 < \beta\rho < 1$, i.e. for any parameters of the penalty function. This case is illustrated in Figure 1 above. Also when *a* takes intermediate values, i.e. $2c < a < 5c$, the overall cartel price under the sophisticated revenue-based regime can be below that under the overcharge-based regime if toughness of both regimes is sufficiently high, i.e. $\frac{5c-a}{3(a-c)} < \beta\rho < 1$. So, in the above mentioned circumstances the sophisticated revenue-based regime welfare dominates the overcharge-based regime. Only for the range of low levels of demand parameter *a* , i.e. when $c < a \leq 2c$, the price implied by the overcharge-based regime will be unambiguously lower than that implied by the sophisticated revenue-based regime for all.

Using the expressions for overall cartel prices derived in section 3.1 and assuming that Δ is uniformly distributed on [0,1], we can calculate the average overcharge, the average consumer surplus, and the average total welfare associated with any penalty regime. These are given by

$$\overline{O}\left[\beta\rho F(\cdot)\right] = \int_0^1 p\left[\Delta, \beta\rho F(\cdot)\right] d\Delta - c \tag{19}$$

$$\overline{CS}\left(\beta\rho F(\cdot)\right) = \int_0^1 CS\left[p\left(\Delta, \beta\rho F(\cdot)\right)\right] d\Delta \tag{20}$$

$$\overline{TW}\left(\beta\rho F(\cdot)\right) = \int_0^1 TW\left[p\left(\Delta, \beta\rho F(\cdot)\right)\right] d\Delta \tag{21}$$

This gives us the following proposition:

Proposition 2: *If we impose* <u>*deterrence equivalence*</u> i.e. $\beta\tilde{\rho}_{SR} = \beta\rho_O = \beta\rho$, *then when* $a \geq 5c$ *or when* $2c < a < 5c$ and $\frac{5c-a}{3(a-c)} < \beta\rho < 1$ *we have*

(i) $\overline{O}_{SR}\left(\beta\rho\right) < \overline{O}_{O}\left(\beta\rho\right)$

(ii) $\overline{CS}_{SR}\left(\beta\rho\right) > \overline{CS}_{O}\left(\beta\rho\right)$

(iii) $\overline{TW}_{SR}\left(\beta\rho\right) > \overline{TW}_{O}\left(\beta\rho\right)$.

Proof of Proposition 2: (i) follows by using (13) and (16) and integrating over all $\Delta \in [0,1]$. (ii) and (iii) follow by noting that consumer surplus and total welfare are strictly decreasing functions of cartel price. ■

This proposition implies that, when demand parameter a is sufficiently high, i.e. $a \geq 5c$, and when the toughness of both regimes is sufficiently high, i.e. $\frac{5c-a}{3(a-c)} < \beta\rho < 1$, the sophisticated revenue-based regime welfare dominates the overcharge-based regime. Only for the range of low levels of demand parameter a, i.e. $c < a \leq 2c$, the overcharge-based regime will unambiguously welfare dominate the sophisticated revenue-based regime independent of the toughness of the penalty regimes

4. Conclusions

We analyse homogeneous product linear demand oligopoly model with price competition and demonstrate that sophisticated revenue-based penalties, in which the penalty rate that is applied to revenue rises linearly with the level of overcharge, can welfare-dominate the overcharge-based penalties for a large range of parameter values.

References

Allain, M., M. Boyer and J. Ponssard (2011). "The determination of optimal fines in cartel cases: Theory and practice". *Concurrences - Competition Law Journal* 4-2011, 32-40

Bageri, V., Y. Katsoulacos and G. Spagnolo (2013), "The Distortive Effects of Antitrust Fines Based on Revenue", *The Economic Journal*, 123 (572), 545-557.

Becker, G.S. (1968), "Crime and Punishment: An Economic Approach", *Journal of Political Economy*, 76, 169-217.

Bos, I. and M.P. Schinkel (2006), "On the Scope for the European Commission's 2006 Fining Guidelines under the Legal Maximum Fine", *Journal of Competition Law and Economics*, 2, 673-682.

Bos, I., S. Davies, J. Harrington and P. Ormosi, (2017), "Does enforcement deter cartels? A tale of two tails", *mimeo*, June 2017, URL: http://assets.wharton.upenn.edu/~harrij/papers.html

Boyer and Kotchoni (2015), "How Much Do Cartel Overcharge?" *Review of Industrial Organization*, 47, 119-153.

Buccirossi, P. and G. Spagnolo (2007), "Optimal Fines in the Era of Whistle blowers - Should Price Fixers Still Go to Prison?" in *The Political Economy of Antitrust*, by V. Goshal and J. Stennek (Eds.), Elsevier: Amsterdam.

Chen, Z. and P. Rey (2013), "On the design of leniency programs," *Journal of Law and Economics,* 56, 917-957.

Connor, J.M. and Y. Bolotova (2006), "Cartel overcharges: Survey and meta-analysis", *International Journal if Industrial Organization,*24, 1109-1137.

Connor, J.M. and R.H. Lande (2008), "Cartel Overcharges and Optimal Cartel Fines", in S.Waller (ed), Issues in *Competition Law and Policy* , Vol 3, AMA Section of Antitrust Law, Chapter 88.

Harrington, J. (2004) "Cartel Pricing Dynamics in the Presence of an Antitrust Authority," *The Rand Journal of Economics* 35, 651-673.

Harrington, J. (2005) "Optimal Cartel Pricing in the Presence of an Antitrust Authority," *International Economic Review* 46, 145-170.

Harrington, J. (2010), "Comment on Antitrust Sanctions", *Competition Policy International,* 6, 41-51.

Houba, H., E. Motchenkova, and Q. Wen (2010), "Antitrust enforcement with price-dependent fines and detection probabilities," *Economics Bulletin*, 30(3), 2017-2027.

Houba, H., E. Motchenkova, and Q. Wen (2017), "Legal Principles in Antitrust Enforcement", forthcoming in *The Scandinavian Journal of Economics,* http://dx.doi.org/10.1111/sjoe.12234

Katsoulacos, Y. and D. Ulph (2013) "Antitrust Penalties and the Implications of Empirical Evidence on Cartel Overcharges", *The Economic Journal*, 123 (572), 558-581.

Katsoulacos, Y., E. Motchenkova and D. Ulph, (2015). "Penalizing Cartels: The Case for Basing Penalties on Price Overcharge", *International Journal of Industrial Organization*, 42, pages 70-80.

Katsoulacos, Y., E. Motchenkova and D. Ulph, (2017). "Penalising on the basis of the severity of the offence: A sophisticated revenue-based cartel penalty", TI Discussion Paper Series; vol. 17, no. 120/VII)

Landes, W. M. (1983), “Optimal Sanctions for Antitrust Violations”, *The University of Chicago Law Review*, 50, 652-678.

Levenstein, M.C. and V.Y. Suslow (2011), “Breaking Up Is Hard to Do: Determinants of Cartel Duration”, *Journal of Law and Economics* 54, 455- 92.

Levenstein, M.C. and V.Y. Suslow (2012), “Cartels and Collusion - Empirical Evidence”. Ross School of Business Paper No. 1182. Available at SSRN: http://ssrn.com/abstract=2182565

Levenstein, M.C. and V.Y. Suslow (2014) “Price fixing hits home: an empirical study of price fixing conspiracies in the US”, mimeo, University of Michigan, Jan. 2014.

Motta, M. and M. Polo (2003), “Leniency Programs and Cartel Prosecution”, *International Journal of Industrial Organization,* 21, 347-379.

OECD Report (2002) “Fighting Hard-Core Cartels: Harm, Effective Sanctions and Leniency Programs”.

Schinkel M.P. (2007), “Effective Cartel Enforcement in Europe”, *World Competition* 30(4), 539-572.

Spagnolo G. and C. Marvão (2016), “Cartels and Leniency: Taking stock of what we learnt”, Handbook of Game Theory and Industrial Organization, Edward Elgar Publishing, 2016.

Veljanovski, C. (2007), “Cartel Fines in Europe: Law, Practice and Deterrence”, *World Competition* 29.

Research Memoranda of the School of Business and Economics of the past five years

2018

2018-1	Yannis Katsoulacos Evgenia Motchenkova David Ulph	Sophisticated revenue-based cartel penalties vs overcharge-based penalties, 14 p.

2017

2017-1	Enno Masurel Roxanne Snellenberg	Does the lifestyle entrepreneur exists? An analysis of lifestyle entrepreneurs compared with other entrepreneurs on the basis of the development of entrepreneurial competences, 14 p.

2016

2016-1	Piet Donselaar Carl Koopmans	The fruits of R&D: Meta-analyses of the effects of Research and Development on productivity, 68 p.
2016-2	Nahom Ghebrihiwet	FDI Technology Spillovers in Extractive Industries: Lessons from Practice, 29 p.
2016-3	Panayiotis Sophronidis John Steenbruggen Henk J. Scholten Maria Giaoutzi Luis Bausa Lopez	An empirical approach to the assessment of the effectiveness of network-centric support tools for flood-emergency response: Results of a field exercise, 48 p.

2015

2015-1	Maurice de Kleijn Rens de Hond Oscar Martinez-Rubi Pjotr Svetachov	A 3D Geographic Information System for 'Mapping the Via Appia', 11 p.
2015-2	Gilberto Mahumane Peter Mulder	Introducing MOZLEAP: an integrated long-run scenario model of the emerging energy sector of Mozambique, 35 p.
2015-3	Karim Abbas Joost Berkhout Bernd Heidergott	A Critical Account of Perturbation Analysis of Markovian Systems, 28 p.
2015-4	Nahom Ghebrihiwet Evgenia Motchenkova	Technology Transfer by Foreign Multinationals, Local Investment, and FDI Policy, 31 p.
2015-5	Yannis Katsoulacos Evgenia Motchenkova David Ulph	Penalizing Cartels: The Case for Basing Penalties on Price Overcharge, 43 p.
2015-6	John Steenbruggen Emmanouil Tranos Piet Rietveld †	Can Motorway Traffic Incidents be detected by Mobile Phone Usage Data? 21 p.
2015-7	Gilberto Mahumane Peter Mulder	Mozambique Energy Outlook, 2015-2030. Data, Scenarios and Policy Implications. 47 p.

2015-8	John Steenbruggen Maarten Krieckaert Piet Rietveld † Henk Scholten Maarten van der Vlist	The Usefulness of Net-Centric Support Tools for Traffic Incident Management, 32 p.
2015-9	Jelke J. van Hoorn Agustín Nogueira Ignacio Ojea Joaquim A.S. Gromicho	A note on the paper: Solving the job-shop scheduling problem optimally by dynamic programming, 12 p.
2015-10	Joost Berkhout Bernd Heidergott	The jump start power method: A new approach for computing the ergodic projector of finite Markov chain, 19 p.

2014

2014-1	John Steenbruggen Emmanouil Tranos Peter Nijkamp	Data from mobile phone operators: A tool for smarter cities? 22 p.
2014-2	John Steenbruggen	Tourism geography: Emerging trends and initiatives to support tourism in Morocco, 29 p.
2013-35	Marco Modica Aura Reggiani Peter Nijkamp	Are Gibrat and Zipf Monozygotic or Heterozygotic Twins? A Comparative Analysis of Means and Variances in Complex Urban Systems, 34 p.
2013-36	Bernd Heidergott Haralambie Leahu Warren Volk-Makarewicz	A Smoothed Perturbation Analysis Approach to Parisian Options, 14 p.
2013-37	Peter Nijkamp Waldemar Ratajczak	The Spatial Economy – A Holistic Perspective, 14 p.
2013-38	Karima Kourtit Peter Nijkamp Eveline van Leeuwen	New Entrepreneurship in Urban Diasporas in our Modern World, 22 p.